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(54) Method for producing control signals, method of controlling signal transfer and a hearing device

(57) Acoustical signals from the acoustical surrounding (U) which impinge upon a reception unit 30 are evaluated and direction of arrival (DOA) of such signals is determined. From signals indicative of such direction of arrival (DOA) a histogram is formed in unit 32. The

behaviour of such histogram is classified under different aspects or criteria and dependent on classification results in a classifying unit 34 the hearing device and thereby especially its signal transfer characteristic from input acoustical signals to output mechanical signals is controlled or adjusted.

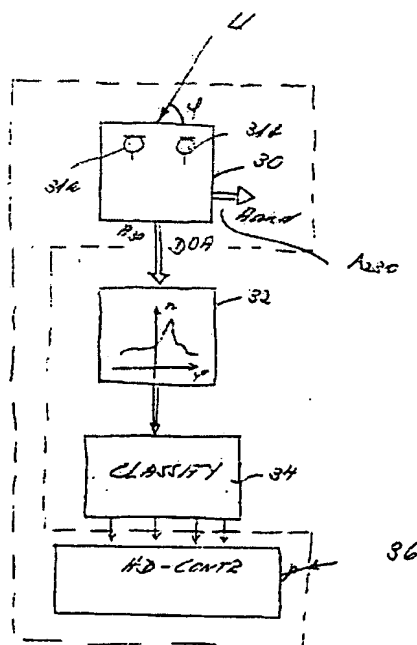


Fig 7

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Description

[0001] The present invention is generically directed under a first aspect on the control of signal transfer characteristics of acoustical signals impinging upon the sensing area of a hearing device to electrical signals for driving at least one electrical/mechanical output converter of such a device and under a second aspect on binaural hearing device systems which necessitate a communication link between a device arranged in or adjacent one ear and a device in or adjacent the other ear of an individual. The one-ear device comprises at least an arrangement of input acoustical/mechanical converters whereas the other ear device at least comprises an output electrical/mechanical converter. Both aspects are thereby most preferably combined.

[0002] Under the first aspect, from the WO 02/32208 according with US application no. 10/059059, the WO 01/20965 accordingly the US application no. 2002-0037087 or from the WO 01/22790 according to US application no. 2002/0090098 different techniques have become known by which the acoustical surrounding of an individual carrying a hearing device and thereby preferably a hearing aid device, may be classified and the transfer characteristic between the acoustical input signal to such a device and mechanical output signal of such device is controlled or adjusted according to such classifying result. The present invention is directed to exploiting a specific criterion of acoustical surrounding of the individual and thus of the hearing device on one hand for producing or manufacturing a respective control signal for such transfer characteristic, on the other hand for positively controlling such transfer characteristic of a hearing device.

[0003] According to the most generic aspect of the present invention under its first aspect such criterion of the acoustical surrounding is the angular location of acoustical sources within such surrounding. The above mentioned object of the present invention is resolved on one hand by a method for producing control signals or -data at a hearing device for controlling the signal transfer characteristic of acoustical signals impinging on said device to electrical signals driving at least one electrical/mechanical output converter of said device which comprises the steps of generating first signals or data which are indicative of direction of arrival of acoustical signals impinging on a sensing area of the device and further generating the said control signals or -data in dependency of the first signal or data. Further the object outlined above is resolved according to the present invention by a method of controlling signal transfer characteristic of acoustical signals impinging on a sensing area to electrical signals driving at least one electrical/mechanical output converter of the hearing device which comprises the steps of generating at said device first signals or data which are indicative of direction of arrival of acoustical signals impinging on the sensing area of such device and controlling the signal transfer with control signals or

data in dependency of the first signals or data.

[0004] The angular positions of acoustical sources in the acoustical surrounding of the device are thereby determined by generating the first signals or data which are indicative of direction of arrival. As will be seen exploiting such direction of arrival DOA allows classifying the acoustical surrounding under many criteria additional to just angular localisation of acoustical sources.

[0005] In a most preferred embodiment of the present invention the control signal or -data are realised in dependency of the first signals or data, in that there is generated from a signal or data which depends from the first signal or data a histogram, and the control signals or data are generated in dependency of such histogram. By forming a histogram from signals which are indicative of DOA the time evolution of acoustical surrounding is monitored somehow like low-pass filtering. Short term variations of the acoustical surrounding are filtered out and there remains in the histogram information about more relevant and persisting characteristics of the acoustical surrounding.

[0006] Thereby an accurate estimation of the prevailing acoustical surrounding becomes possible.

[0007] In a further preferred embodiment of the present invention the histogram as generated is classified and different control signals or data are generated in dependency of the result of such classifying.

[0008] We understand under classification of a histogram watching different characteristics of such histogram as e.g. peak-magnitude, peak-width, relative positioning of such peaks, time evolution etc. and establishing which characteristics of the acoustical surrounding lead to which characteristics or combination of characteristics in the histogram as a bases for appropriately setting or controlling the transfer characteristic of the device. Thereby the acoustical surrounding is considered related to the device which receives the acoustical signals so that not only different behaviours of the acoustical surrounding itself but additionally some behaviour of the device and thus of the individual in the acoustical surrounding may be evaluated or detected.

[0009] In a preferred mode of operating the methods according the present invention the histogram function is classified according to at least one of the following aspects or criteria:

- how is the angular location and/or its evolution of an acoustical source with respect to the hearing device and/or with respect to other sources
- what is the distance and/or its evolution of an acoustical source with respect to the device and/or with respect to other acoustical sources
- which is the significance of an acoustical source with respect to other acoustical sources

- how is the angular movement of the device itself and thus of the individual with respect to the acoustical surrounding and thus to acoustical sources.

[0010] The control signals or data are generated in dependency of the result of such classifying at least under at least one of said criteria i.e. in dependency of the answers electronically found under such criteria. In a further preferred embodiment of the methods according to the present invention the hearing device is provided with a beamformer characteristic. Such a beamformer characteristic defines for amplification between an acoustical signal which impinges on the device's sensing area and an electrical signal or data in dependency of direction of arrival of the acoustical signal with respect to the sensing area. Thereby controlling the addressed signal transfer characteristic at least comprises controlling the beamformer characteristic.

[0011] By generating the first signal or data indicative of direction of arrival of an acoustical signal it is e.g. possible to determine whether the beamformer's amplification characteristic has its maximum at that angle which accords with the DOA angle. If it hasn't and if the source at the specific DOA is to be accurately tracked, the beamformer is e.g. adjusted to shift its maximum amplification angle so as to coincide with the DOA. Thereby source tracking is performed. In analogy a source under a detected DOA may be cancelled as at least momentarily of no interest, by shifting low- or zero-amplification of the beamformer to occur at the specific DOA of that source.

[0012] Also under this beamformer control aspect it is preferred to generate in dependency of the first signals or data (DOA-indicative) a histogram and controlling at least the beamformer characteristic of the device in dependency of such histogram.

[0013] With respect to the advantages of subjecting direction of arrival indicative signals to histogramming, the same prevails as was outlined above.

[0014] In analogy to the above addressed classifying technique in a still further preferred embodiment the histogram is classified and different control signals or data which at least control the beamformer characteristic are generated in dependency of the result of such classifying. Further classifying the histogram comprises classifying such histogram under at least one of the following criteria:

- how is the angular location and/or its time evolution of an acoustical source with respect to the device and/or with respect to other sources
- what is the distance and/or its time evolution of an acoustical source with respect to the device and/or with respect to other sources
- what is the significance of an acoustical source with respect to other acoustical sources

- how is the angular movement of the device itself with respect to the acoustical surrounding.

[0015] Thereby controlling at least the beamformer characteristic is performed in dependency of the result of the classifying which comprises classifying under at least one of the said criteria.

[0016] Under a further most preferred embodiment, primarily directed on a binaural hearing device, the methods according to the present invention comprise the steps of generating the first electric signal in dependency of acoustical signals which impinge upon a first acoustical receiver. Second electrical signals are generated in dependency of acoustical signals impinging upon a second acoustical receiver. A first electrical/mechanical output converter is driven by a third electrical signal whereas a second electrical/mechanical converter is driven by a forth electric signal. By control signals or data generated according to the present invention, at least one of the following signal transfer characteristics is controlled and adjusted:

- transfer characteristic from the first electric signal to the forth electric signal
- transfer characteristic from the second electric signal to the forth electric signal
- transfer characteristic from the first electric signal to the third electric signal
- and finally transfer characteristic from the second electric signal to the forth electric signal.

[0017] Thereby considering the two acoustical receivers provided and the two electrical/mechanical output converters provided, by the said transfer characteristics the influence of each of the said acoustical receivers upon each of the said output converts may be controlled or adjusted respectively in a preferred realisation form.

[0018] Again in a preferred realisation form the at least one transfer characteristic and thereby in a further preferred embodiment all the four transfer characteristics as mentioned are controlled by exploiting a histogram of a signal which is dependent from at least one of the first and of the second electric signals and thus from the acoustical signals impinging upon the first and/or second acoustical receivers.

[0019] In a still further embodiment such histogram is classified and the at least one of said transfer characteristics is controlled in dependency of the result of classifying. Thereby classifying is preferably performed at least under at least one of the above mentioned classification criteria.

[0020] In a most preferred embodiment of the method performed with at least two acoustical receivers and the two electrical/mechanical output converters, at least one head related transfer-function HRTF is reintroduced

by respectively adjusting the at least one of the said transfer characteristics. This is done in the transfer characteristics from the first signal to the forth signal and/or from the second signal to the third signal.

[0021] As an example:

[0022] Whenever an acoustical source becomes or is angularly located so that, considered from one acoustical receiver, it appears acoustically shadowed or masked by the individual's head, whereas, considered from the other acoustical receiver it is directly acoustically seen, on one hand the acoustical signal to the first mentioned masked receiver will be significantly smaller than the acoustical signal impinging on the unmask receiver so that reception of that acoustical signal at the unmask receiver will be more accurate e.g. with respect to signal to noise. Therefore it might be advantageous not only to drive the output converter adjacent to the unmask receiver primarily in dependency of its output signal, but also to drive the other output converter adjacent to the masked acoustical receiver primarily in dependency of that signal with high SNR. Nevertheless in such a case the signal transfer characteristic from the unmasked receiver to the output converter adjacent the masked receiver should re-establish the HRTF i.e. the masking effect of individuals head, so as to allow the individual to perceive the acoustical signal of that source spatially correct.

[0023] A hearing device according to the present invention and resolving the above mentioned object has an acoustical/electrical input converter arrangement with an output, an electrical/mechanical output converter arrangement with an input, a direction of arrival determining unit with an input operationally connected to the output of the acoustical/electrical converter arrangement which generates at an output a signal or data indicative of direction of arrival of acoustical signals impinging on the acoustical/electrical input converter arrangement. There is further provided a controlled signal transfer unit, the input thereof being operationally connected to the output of the acoustical/electrical input converter arrangement; the output thereof being operationally connected to the input of the electrical/mechanical output converter arrangement. The controlled signal transfer unit provides for controlled signal transfer between the input and the output and has a control input which is operationally connected to the output of the direction of arrival determining unit.

[0024] Further preferred embodiment of the methods according to the present invention under its first aspect as well as of the device according to the present invention under that aspect will become apparent to the skilled artisan when reading the following description of preferred embodiments of the present invention as well the appending claims.

[0025] Under the second aspect of the present invention, most preferably combined with the first one, from the WO 99/43185 such a binaural hearing device system is known, whereat each device associated to an ear

comprises an input acoustical/electrical converter and an output electrical/mechanical converter. There is further provided a communication link between the two devices whereby data or signals are cross communicated via such link which are respectively dependent from the output signals of the respectively provided acoustical/electrical input converters. Thereby before the respective converter output signals are applied to the communication link they are analogue/digital converted whereby there may be implemented in the respective analogue/digital converters some additional signal preprocessing. Further such a system is known from the US 2002-004695A1. Location of the communication link appears to be unambiguously defined.

[0026] Today's monaural hearing devices customarily have at least two input acoustical/electrical converters for beamforming purposes. The binaural system according to the WO 99/43185 may be tailored to provide beamforming by using the two input converters provided at the respective one ear attributed devices. Thereby, as outlined above, data are cross-transmitted via the communication link which are possibly preprocessed but which comprise substantially more information than really needed. Further beamforming with two input converters placed one on each side of individuals head may be quite complex and inaccurate e.g. due to the head-related acoustical transfer functions' HRTF which describe the effects of acoustical signals being "shadowed" by individuals head. Such shadowing occurs, dependent on direction of arrival of acoustical signals, asymmetrically with respect to both ears which on one hand allows spatial perception, on the other hand renders beamforming quite complex.

[0027] It is an object of the present invention under its second aspect to provide a binaural hearing device system and respectively a method for controlling such hearing device system whereat the technique of providing at least two input acoustical/electrical converters at one ear's device is maintained as known from monaural devices and additionally there is nevertheless applied to the communication link only one signal or data which is thereby dependent from the output signals of both of the at least two input converters at one ear's device. Thereby a significantly reduced amount of data is transmitted via said link compared with a case where, following the concept of the WO 99/43185, output signals of each input converter are separately transmitted via the link.

[0028] This object is resolved by the binaural hearing device system according to the present invention which comprises a first device for one ear of an individual, a second device for the other ear, a data/signal communication link between the first and the second device whereby the first device comprises at least a reception unit with at least two input acoustical/electrical converters and a signal processing unit the inputs of which being operationally connected to the electrical outputs of the at least two converters and which generates at a

combined output a signal which is dependent on signals at both the said inputs whereby the signal link is provided at the output side of such processing unit and transmits data signals which depend upon the output signal of the processing unit whereby the second device comprises at least an output electrical/mechanical converter.

[0029] As is known to the skilled artisan there exist so called Complete-In-the-Channel, CIC-hearing devices whereat, due to complete introduction in the ear channel only one input acoustical/electrical converter is provided. Thereby whenever instead of the device mentioned above with at least two input converters, a CIC with only one input acoustical/electrical converter is to be applied according to the present invention's general concept, significant information and data reduction is achieved before transmitting data to the communication link. In that there is provided between the output of the one input converter and the communication link, a Wiener-Filter.

[0030] As was mentioned above the system according to the present invention provides in one embodiment the first device to be applied to one ear not having an electrical/mechanical output converter and thus only having in a reception unit the at least two acoustical/electrical input converters. This embodiment might be most valid e.g. if on any reason it is not possible to apply a device with at least two input converters at that ear where hearing shall be improved.

[0031] Thereby the second device does not comprise an input acoustical/electrical converter irrespective whether the first device has an output converter or not.

[0032] In a further preferred embodiment an output electrical/mechanical converter provided at the first device is operationally connected to the output of the processing unit and is thus driven by a combined signal or data dependent on both outputs of the at least two input acoustical/electrical converters provided.

[0033] In a still further preferred embodiment the system according to the present invention has the reception unit of the first device as a first reception unit whereby the at least two input acoustical/electrical converters thereat are first acoustical/electrical converters. Additionally the signal processing unit still at the first device is a first signal processing unit.

[0034] Further the output electrical/mechanical converter at the second device is considered as a second output electrical/mechanical converter. The first device comprises a first output electrical/mechanical converter and the second device a second reception unit.

[0035] Thus both devices for each of the two ears have respective reception units and thus input acoustical/electrical converters and respective output electrical/mechanical converters.

[0036] Nevertheless the second reception unit at the second device needs not necessarily have more than one input acoustical/electrical converter although providing also there at least two input acoustical/electrical

converters is preferred.

[0037] Further the communication link which is provided in all embodiments according to the present invention, for communicating between devices adjacent or in the respective ears, maybe wirebound and/or based on optical fiber and/or on wireless communication.

[0038] Whenever both ears devices are equipped with input acoustical/electrical converters in a preferred embodiment both devices are equipped with at least two of such converters which gives the possibility to provide at both devices beamforming ability. Thereby further preferably also the second reception unit is equipped with a signal processing unit whereby, further preferred, the inputs of such processing unit are operationally connected to the electrical outputs of the second input converters at the second reception unit. This processing unit generates at a respectively second output a signal which is dependent on signals at both said inputs of the second signal processing unit whereby the signal link is provided at the output side of the second signal processing unit. Thus via the addressed signal or communication link combined signals dependent respectively on the output signal of at least two input converters are bidirectionally transmitted from one device to the other and vice versa.

[0039] Thereby and in a further preferred mode or embodiment the output of the first signal processing unit is operationally connected to a first input of a weighting unit and the output of a second signal processing unit is operationally connected to a second input of the weighting unit. The weighting unit has a first output which is operationally connected to an input of a first output converter and has a second output which is operationally connected to the input of the second output converter. Thereby the weighting unit may be construed decentralised e.g. in both devices. The weighting unit has a control input and varies operational connection or signal transfer between the first input and the first output, the first input and the second output, the second input and the first output and finally the second input and the second output. Such signal transfers are controlled by a signal or data applied to the control input of said weighting unit. Thereby such operational connections between respective inputs and outputs are formed preferably frequency or frequency-band specifically and the respective functions which are controlled independently from one another are possibly but not necessarily complex functions.

[0040] So as to determine how the operational connections between respective inputs and outputs at the weighting unit have to be controlled, especially according to the acoustical surrounding present, the control input of the weighting unit is preferably connected to an output of a classification unit which later has at least one input operationally connected to an output of at least one of the reception units.

[0041] In a further most preferred embodiment the

first device comprises a beamformer unit which has a beamcontrol input and an output. Via the beamcontrol input the directional characteristic of the beam as an amplification characteristic in dependency of spatial angle at which an acoustical signal impinges on the device, may be varied.

[0042] There is further provided a detection unit for detecting the direction of arrival of an acoustical signal which impinges upon the reception unit which unit generates at an output an output signal in dependency of said direction of arrival. This output is operationally connected to the beamcontrol input of the beamformer unit so that e.g. a source of acoustical signal the direction of arrival of which having been detected may be more accurately tracked by accordingly directing a maximum amplification direction of the beam upon such a source. Accordingly a source, as e.g. a noise source, the direction thereof having been detected may be cancelled by controlling the beam so that it establishes in that noise source direction minimum amplification.

[0043] As was mentioned above in a preferred embodiment there is provided a weighting unit whereat signal transmission between respective inputs and outputs is controlled. Thereby control of such signal transmission is made dependent from the result achieved in a classification unit the input thereof being operationally connected to at least one output of at least one of the reception units.

[0044] Departing from this embodiment and in a further preferred mode there is provided at the system a determination unit for the direction of arrival of an acoustical signal impinging on at least one of the devices whereby such direction determination unit is interconnected between at least one input of the classification unit and at least one output of at least one of the reception units at the devices.

[0045] Thus the classification which finally controls signal transfer at the weighting unit at least comprises classification of signals which depend on direction of arrival. Thereby and as a further improvement of such embodiment there is provided at least one histogram forming unit, the input thereof being operationally connected to at least one output of at least one of the reception units. The output thereof is operationally connected to an input of the classification unit. Thus classification at least comprises classification based on a histogram result. Most preferably and with an eye on providing a direction of arrival determination unit such histogram forming unit is provided with an input operationally connected to an output of the determination unit and an output operationally connected to the classification unit. Thereby classification at least comprises classification of a histogram function of a signal or of signals which identify such direction of arrival.

[0046] The object mentioned above still further is resolved by the method for controlling a hearing device system which comprises at least a reception unit at a first device for one ear which has at least two inputs

acoustical/electrical converters and at least an output electrical/mechanical converter at a second device for the other ear and a communication link between the first and the second device which method comprises the steps of generating in dependency of output signals of the at least two input converters a combined signal and transmitting such combined signal via the communication link.

[0047] For applying the method according to the present invention to CIC hearing devices the method according to the invention comprises providing instead of the at least two input converters only one converter and construing the first device as a device to be completely introduced into the ear channel and further comprises a step to treat the output of the one input converter by a Wiener-Filter and transmitting signals dependent from the output of the Wiener-Filter via the communication link.

[0048] The present invention and the object thereof is further resolved by the method for producing a drive signal for a electrical/mechanical output converter of a binaural hearing device which method comprises the steps of acoustical/electrical converting impinging acoustical signals at at least two input converters of a device to be applied adjacent individuals one ear, transmitting a combined signal dependent from both said convertings via a link to a further device to be applied adjacent or in individuals other ear and generating the drive signal in dependency of the transmitted signal.

[0049] Further preferred embodiments of the methods according to the present invention under its second aspect as well as of the system according to the present invention under this second aspect will become apparent to the skilled artisan when reading the following description of preferred embodiments of the present invention as well as the claims. As mentioned above the invention under its first aspect is most preferably improved in being combined with the invention under its second aspect.

[0050] The present invention under both and combined aspects will now be further described with the help of figures. They show examples of preferred embodiments, namely:

Fig. 1 By a schematic, simplified functional-block/signal-flow representation, a first embodiment of the system according to the present invention and operated according to the methods of the present invention;

Fig. 2 in a representation form in analogy to that of fig. 1 a further embodiment of the present invention;

Fig. 3 again in a simplified schematic functional-block/signal-flow representation a still further embodiment according to the present invention again operating according to the meth-

ods of the present invention;

Fig. 4 still in the same representation form a further embodiment of the present invention;

Fig. 5 by means of a simplified schematic functional-block/signal-flow representation a subembodiment for automatic beamcontrol e.g. to track acoustical sources and/or to cancel reception of acoustical sources. Such embodiment may preferably be incorporated within the embodiments according to the present invention;

Fig. 6 departing from a system or methods according to fig. 4 still in a simplified schematic functional-block/signal-flow representation an improved embodiment of such system or methods;

Fig. 7 by means of a simplified schematic functional-block/signal-flow representation a system or method for controlling a hearing device as a function of direction of arrival of acoustical signals as detected and preferably classified;

Fig. 8 examples of direction of arrival behaviours as appearing on a histogram function to explain some of more simple classification criteria as preferably exploited at the system or methods of fig. 7 as well as at systems or methods to be shown with the help of the fig. 9 and 10;

Fig. 9 in form of a simplified schematic functional-block/signal-flow representation an improved and today preferred form of an embodiment of the system according to the present invention and of the methods according to the present invention;

Fig. 10 departing from the representation of fig. 9 a more detailed representation of such system or methods making use of direction of arrival detection as described in more details in the WO 00/68703 which accords with the US application no 09/636 443 and 10/180 585.

[0051] According to fig. 1 a system according to the present invention operating according to the method of the present invention both under a first aspect thereof is schematically shown by means of a simplified functional block/signal flow diagram in a minimal configuration. There is provided an acoustical reception unit 1 with at least two acoustical/electrical converters 3a and 3b, both with a respective acoustical input and an electrical output. Reception unit 1 may incorporate e.g. respective analog to digital converters connected to the outputs of the converters 3a, 3b, time domain to fre-

quency domain conversion units downstream such analog to digital converters and has a signal processing unit 4 for processing signals in dependency of the analog signals appearing at the outputs of the converters 3a, 3b. Processing unit 4 generates at an output A₁ of reception unit 1 a signal or data which is result of combined processing of signals dependent on the output signals of both converters 3a and 3b. The output signal at A₁ depends on the output signals of both converters 3a, 3b. This signal or data at output A₁ possibly further processed at respective signal processing units (not shown) generates a signal or data, which is dependent on the output signal or data at A₁, which is transmitted to a transmission link 5, which again may incorporate further signal processing. At the output side of transmission link 5 a signal or data, which is dependent on the signal appearing at the output A₁ of unit 1, is input to an input E₇ of an electrical/mechanical converter unit 7. Unit 1 is applied adjacent or within one of an individual's ears, unit 7 to the other.

[0052] The system as shown in fig. 1 is in a preferred embodiment a hearing aid system i.e. a therapeutical system. Unit 7 is thereby an outside-the-ear or an inside-the-ear converter unit or an implanted or implantable unit. By this minimal system acoustical signals are received on one of individual's ears and control hearing at the other ear. Such a system may be provided, where on any reasons, applying the reception unit 1 is not possible or difficult on that ear where hearing shall be improved or reinstalled.

[0053] The concept of applying a reception unit as of unit 1 at or adjacent one ear and transmitting signals or data dependent on the received acoustical signals at such reception unit to the other ear for improving hearing at that other ear, this concept per se is considered inventive, irrespective of how reception unit, signal link to the other ear and a other's ear converter unit as of unit 7 of fig. 1 are conceived. Under this concept one ear is only provided with an electrical/mechanical unit and no reception unit. The embodiments of figs 1 to 3 clearly fall under such concept. In any case the link 5 may be electric wire based, optical fiber based or may be a wireless communication link.

[0054] The double-line arrows shown in Fig. 1 and following figures represent signal or data communication paths. Along such signal path additional signal processing by respective units may be established. The double-arrows may indicate a direct signal transmission, but rather stand for an operational connection, in which signals are transmitted and processed in direction of the arrow.

[0055] By the system according to fig. 1 only data or signals are transmitted via transmission link 5, which have been preprocessed as by combining signals of at least two acoustical to electrical input converters 3a, 3b.

[0056] In fig. 2 there is shown in a representation, in analogy to that of fig. 1, a second preferred embodiment, which only differs from that of fig. 1 in that unit 1 of fig.

1 is now conceived as a unit 10 to be applied completely introduced in an individual's ear channel, a so-called CIC-device. As known to the skilled artisan such a CIC unit customarily has only one input acoustical to electrical converter 3c. By means of a digital signal processing unit 11, which is operationally connected e.g. via time domain to frequency domain converter and analog to digital converter to the analog output of converter 3c, at least a Wiener-filtering is performed. The output signal or data of converter 3c is processed by a Wiener filter to result in significantly preprocessed data before being transmitted via communication link 5 to the electrical to mechanical converter unit 7.

[0057] In fig. 3 there is shown in a representation in analogy to that of the figs. 1 or 2 a further preferred embodiment of the system according to the present invention, which operates according to the method of the present invention. According to the system of fig. 3, the difference to the system of fig. 1 is that the output A_1 of reception unit 1 is not only, via transmission link 5, operationally connected to the input E_7 of the electric/mechanic converter unit 7 at the other of individual's ears, but output A_1 is additionally operationally connected to an electrical/mechanical converter unit 7b, which is provided at the same ear as reception unit 1.

[0058] It is evident that in dependency of the signals or data at output A_1 the left ear and the right ear units 7a and 7b have normally to be differently operated. Thus there are generically installed different and/or differently operating signal processing units as on one hand between the output A_1 and link 5, link 5 and input E_{7a} , and on the other hand output A_1 and input E_{7b} of unit 7b. In the case of the embodiment of fig. 3 and as shown in dashed-pointed frame, the units 1 and 7b are preferably incorporated in a unitary hearing device, especially in a hearing aid device being a behind- or an in-the-ear hearing device.

[0059] Instead of providing a reception unit 1 with at least two input acoustical to electrical converters 3a and 3b as of fig. 3, this unit may be construed according to unit 10 of fig. 2, i.e. as a CIC-unit.

[0060] According to the embodiment of fig. 3 there is in fact established a MASTER-acoustical control by reception unit 1 at one ear of the individual, whereas a hearing device without an input acoustical to electrical converter unit is operated at the other ear as a SLAVE device.

[0061] Departing from the system and method as explained with the help of fig. 3 a further preferred embodiment of the invention under the first aspect thereof is shown in fig. 4, still in a representation in analogy to that of the figures 1 to 3.

[0062] According to the system of fig. 4 there is provided for the left ear of an individual a reception unit 1_L and for the right ear a reception unit 1_R . Both reception units 1_L and 1_R are conceived with respect to signal or data processing as was explained with respect to reception unit 1 in context with fig. 1. Instead of units 1_R and

1_L being conceived according to unit 1 of fig. 1, one or both thereof may be conceived according to unit 10 of fig. 2. A signal or data dependent from the signal or data at the output A_{1L} of reception unit 1_L is fed to an input E_{9L} of a selection unit 9. A signal or data which is dependent from the signal or data appearing at the output A_{1R} of the right ear reception unit 1_R is fed to an input E_{9R} of the selection unit 9. There is further provided a left ear electrical/mechanical output converter unit 7_L and a right ear electrical/mechanical output converter unit 7_R .

[0063] The selection unit 9, as schematically shown by a switching arrangement, has an output A_{9L} and an output A_{9R} respectively operationally connected to the inputs of output converters 7_L , 7_R . Signals or data appearing at either of the outputs A_{9L} or A_{9R} may operationally be connected to both electrical to mechanical converter units 7_L and 7_R . Under the control of a selection-control unit 12 and, as schematically shown in unit 9 by an arrangement of switches, the input E_{9L} or the input E_{9R} is operationally connected to both of the converters 7_L , 7_R . Thereby, whenever the operational signal or data connection within selection unit 9 is established according to that switching position shown in fig. 4, both converters 7_L and 7_R are operationally connected to the right ear reception unit 1_R , and therefore the right ear reception unit 1_R is the MASTER. In analogy, unit 1_L becomes MASTER whenever the units 7_L and 7_R are operationally connected to the input E_{9L} of selection unit 9.

[0064] In this embodiment again the right ear units 1_R and 7_R are preferably incorporated in a unitary right ear hearing device, be it a hearing aid device or be it a hearing device for other than therapeutical appliances. In analogy the units 1_L and 7_L are incorporated in a respective left ear unitary device. Such hearing devices may thereby be in-the-ear or outside-the-ear hearing devices or their output converters 7_L and/or 7_R may be construed as implantable devices. Further, the right and left ear devices do not necessarily have to be of the same type, e.g. an in-the-ear and an outside-the-ear hearing device may be combined, an outside-the-ear and an implant device etc.

[0065] Looking back on fig. 3 it has been shown that the acoustical signal impinging on unit 1 at one ear, e.g. at the left ear, binaurally controls both electrical to mechanical output converter units 7a and 7b. We have established that double-lined arrows stand for operational signal or data communication and not necessarily for direct connection. Thus, along operational connections processing as by processing units, especially DSP's, may be done. For example: As according to fig. 3 the acoustical signals impinging on unit 1 do control both output converters 7 and thus the head-related transfer function HRTF for the SLAVE side with converter 7a is lost, there will preferably be provided as shown in dashed line a DSP 13 exclusively influencing signals or data input to the SLAVE converter 7a and whereat the respective HRTF is taken into account. So as to

properly set the parameters of processing in DSP unit 13 for taking the HRTF functions into account, the reception unit 1 detects direction of arrival DOA as denoted by ϕ in fig. 3 and there will be transmitted additionally to the signal or data dependent from those appearing at output A_1 of unit 1, via link 5, a DOA-significant signal or data to DSP 13 as shown by signal DOA. Further, there will be preferably provided a DSP 14 just upstream the input E_{7b} and DSP 13 or a further DSP to input E_{7a} as well as DSP 14 will take in account different signal processing needs according to the hearing improvement needs at the respective ears.

[0066] When looking to the embodiment of fig. 4 in analogy to the just given explanations with respect to the system of fig. 3, whenever the right ear device is MASTER, the HRTF will preferably be considered for the left ear converter 7_L , i.e. the SLAVE and vice versa. Thus, the left ear HRTF is taken into account by a DSP 16, and the right ear HRTF by a DSP 18. Preferably that one of the units 1L and 1R, which acts as a MASTER, provides for data about direction of arrival DOA (not shown) so as to control the transfer characteristic of the respective HRTF DSP 16 and 18.

[0067] With an eye on Fig. 1 or 2, there the processing unit 4 will preferably take the HRTF of the left side ear into consideration.

[0068] With respect to one preferred possibility for detecting direction of arrival DOA of acoustical signals at the reception units 1, 10, 1L and 1R, we refer to the WO 00/68703 "Method for localizing direction" of the same applicant, wherein a technique for detecting such direction of arrival DOA is completely disclosed, and which shall be incorporated with respect to DOA detection into the present description. This WO 00/68703 accords with US application no. 09/636 443 and no. 10/180 585. Thereby, the reception units 1, 1L, 1R may preferably further comprise beam formers as are e.g. described in the WO 00/54553, according to US application No. 09/267 742, the WO 99/04598, according to US application No. 09/146 784, the WO 99/09786, according to US application No. 09/168 184, all of the same applicant.

[0069] Thus, in one preferred embodiment such units 1, 1L, 1R provide for both, namely beam forming as well as detection of DOA. Thereby, in a further preferred embodiment beamforming is controlled by the DOA.

[0070] This preferred form of realizing the reception units 1, 1L, 1R as discussed up to now is schematically shown in fig. 5. Thereby, the units 1, 1L, 1R comprise a beamforming subunit 20 with at least two input acoustical/electrical converters. At the output of such unit, which accords to output A_1 or A_{1L} , A_{1R} there appear electrical data or signals in dependency of acoustical signals impinging on the at least two input converters and amplified according to a predetermined characteristic in dependency of spatial angle with which the acoustical signals impinge on the input converters. The outputs of the acoustical to electrical converter are fur-

ther exploited e.g. according to the teaching of the WO 00/68703 so as to provide for a signal which is indicative of the direction of arrival DOA of the acoustic signals. Thereby preferably and as described in the said WO 00/68703, there is performed a histogram of the DOA signals, as will be discussed later. The output of a histogram-forming and evaluating unit 22 controls beamformer unit 20 at a control input C_{20} e.g. to track an acoustical source selected with high amplification or to delete such acoustical source by low amplification.

[0071] Turning back to the system of fig. 4, it may be seen that the data link 5, which was shown in the figs. 1 to 3, has not been shown anymore. Such data link, by which signals or data are or is transmitted from one ear side to the other, may be provided in the system as of fig. 5, wherever felt best. The selection unit 9 may e.g. be incorporated in one of the left ear or right ear devices, e.g. in the left ear device and then the addressed data link 5 will be provided at 5' as shown in fig. 5. On the other hand the selection unit 9 may be split into left ear device- and right ear device-units, and then the data link 5 would be established and following the representation of fig. 4 practically within selection unit 9.

[0072] Further, with an eye on fig. 4, this system clearly operates one of the two devices as a MASTER, the other one, and thereby especially the output converter 7 thereof, as a SLAVE. Changing this MASTER/SLAVE relation occurs abruptly and it is not possible to gently control the MASTER/SLAVE weighting of the two devices. This becomes possible by the improvement on fig. 4, which shall be explained with the help of fig. 6.

[0073] According to fig. 6, wherein units which correspond to units already described in context with fig. 4 have been denoted with the same reference number, the selection unit 9_W in fact is a weighting unit. Therein, the influence of a signal or data dependent from such signal or data at output A_{1L} upon signal or data respectively appearing at the outputs A_{9L} and A_{9R} is continuously adjustable, as shown schematically by variable coefficients α , β . In analogy the influence from output A_{1R} upon the two outputs A_{9L} and A_{9R} of unit 9_W is adjusted as schematically shown by variably controllable coefficients γ and δ . The coefficients α , β , γ , δ are preferably frequency dependent or at least dependent from frequency bands and are normally of complex value. These weighting coefficients are controlled by a selection control unit 12_W .

[0074] In the embodiments according to the figs. 5 and 6 there is provided respectively a selection control unit 12 or 12_W not having been described yet. The selection control unit 12 and respectively 12_W are in fact classification units, whereat the instantaneously prevailing acoustical environment and/or the time development in the past up to the present of such acoustical surrounding and even a trend estimation for future development of such acoustical signals is classified according to predetermined criteria as e.g. disclosed in the WO 02/32208 which accords with US application no. 10/059

059 or in the WO 01/20965 according to US application no. 2002-0 037 087 or in the WO 01/22790 according to US application no. 2002-0 090 098. In any case to the classifier and control units 12, 12_w there is input information about the acoustical signals received at units 1, 1_L and/or 1_R as shown at 13 in Fig. 4, at 13a, 13b in Fig. 6. Under a second aspect of the present invention a preferred classification technique shall be described in the following, which is most apt to be combined with the present invention under its first aspect described up to now.

[0075] This second aspect of the invention is schematically shown in fig. 7, by a representation in analogy to that used throughout the figs. 1 to 6. It comprises a reception unit 30 with at least two input acoustical to electrical converters. The unit 30 operates so as to generate an output electrical signal or data at output A₃₀ indicative of the spatial direction of arrival DOA with which an acoustical signal impinges upon the acoustical inputs of the input converters 31a and 31b as provided. Such a unit is known e.g. from the WO 00/68703 which accords with the US application No. 09/636 443 and 10/180 585 of the same applicant. From the instantaneously monitored DOA there is generated by means of a processing unit 32 a histogram function of DOA. This is also known from the WO 00/68703. Thus, under the second aspect of the invention there is formed a histogram of the instantaneously prevailing DOA. According to the second aspect of the invention it is the DOA-histogram which is used as entity for classifying the acoustical signals in unit 34, which impinge upon the unit 30 and for controlling system adjustment especially according to figs. 4, 5, or 6. Thereby and as schematically shown in fig. 7 by dashed-dotted lines, the reception unit 30 is preferably a part of a hearing device system 36. The signals or data representing audio signals are generated by unit 30 at output A₃₀. If that unit 30 performs combined tasks of DOA detection and audio signal processing. The histogram generated at unit 32 is now classified in classifying unit 34, which controls at its output most generically the behavior of a hearing device system, be it a monaural system, but most preferably of a binaural hearing device system as shown in Figs. 1 to 6.

[0076] Accordingly in fig. 8 there is shown more than one output of classifying unit 34 representing different controls to the hearing device system according to different types of histogram appearance and thus of acoustical source behavior in the acoustical surrounding U of fig. 7 of the hearing device system, and thus of an individual carrying such system.

[0077] In fig. 8a there is shown purely as an example such a histogram function represented by the overall time or in fact the overall number n of measuring samples, which result in a specific DOA spatial angle φ . For the DOA φ_0 a relatively sharp peak is present indicating that at that angle φ_0 to the acoustical input of the converters 31a and 31b there is a significant acoustical source in the acoustical surrounding U. At φ_1 there is a

second yet less relevant acoustical source present in the surrounding U.

[0078] Departing from this histogram (a) some possible evaluations in time shall be discussed. According to fig. 8(b) at the DOA φ_0 the peak has become broadened and its amplitude has dropped. This means e.g. that the acoustical source at the angle φ_0 has become diffuse, which may be caused by an increase of distance between the reception unit 30 and the acoustical source in the surrounding U. According to fig. 8(c) and still considered as an evolution in time of the situation as present according to fig. 8(a), it may be seen that the histogram has been shifted by an angle Δ . This means that the reception unit 30 has rotated relative to the acoustical surrounding U, in other words that the individual carrying a system with unit 30 has turned his head by the angle Δ . This is identified because the relative positioning of the sources in the surrounding U according to fig. 8(a) at φ_0 and at φ_1 remains stable.

[0079] According to fig. 8(d) the peak appearing at the DOA φ_0 according to fig. (a) now appears at a different angle φ_2 , whereas the source of at φ_1 according to fig. (a) still appears at the unchanged angle φ_1 . This means that the source at φ_0 according to fig. (a) has moved to the new angular position φ_2 , whereby the reception unit 30 has not rotated, i.e. the individual has kept his head stationary. From these explanations it may be seen which kind of criteria are used in classifying unit 34 of fig. 8 to establish a relevant acoustical source, increasing distance, decreasing relevancy of a source, appearance/disappearance of a source movement of individual's head relative to the acoustical surrounding, angular movement of a source in the surrounding U, etc.

[0080] From combining and adding further classifying criteria an intelligent evaluation of the acoustical surrounding is performed and by the respective results the behavior of the hearing device system 34 is controlled. This may include source tracking by controlling beamforming and/or with an eye back on fig. 5 and 7 appropriate distribution of the influence or signal transfer of binaurally provided reception units upon binaurally provided output converters.

[0081] Thus under the second aspect the present invention is directed on classifying signals or data which are indicative of the DOA and controlling the status or behavior of a hearing device, be it a monaural or binaural device in dependency of the classification result. Thereby most preferably classification is performed upon data or signals wherefrom a histogram has been formed.

[0082] In fig. 9 there is shown a preferred embodiment, which combines the invention under its first aspect realized as was explained with the help of fig. 6 and under its second aspect.

[0083] A left ear reception unit 40_L of a left ear hearing device is conceived as a beamformer with at least two input converters 41_L. The right ear hearing device, as an example, is equally construed as the left ear device

and thus comprises a reception unit 40_R equal to the unit 40_L . In analogy to the representation in fig. 6 at the respective outputs A_{1L} , A_{1R} electrical signals or data are generated as a result of processing the output signals of the converters 41. These signals are thus dependent on the acoustical signal impinging on the reception units, amplified according to the beamformer characteristics. The units 40 preferably comprise a respective beamformer control input BFC_L and BFC_R , by which the shape of the beamformer characteristic, but especially the angle θ of maximal amplification may be adjusted. The units 40 further generate output signals, which are indicative of the DOA of acoustical signals impinging on the acoustical inputs at the units 40. Signals or data dependent from these output signals DOA_L , DOA_R are respectively input to histogram-forming units 44_L , 44_R . The units 40 combined with histogram-forming units 44 may and are preferably realized as described in the WO 00/68703, which accords with the US application No. 09/636 443. Thereby and as seen in this paper the beamformers are based on the delay-and-add/subtract principal and thus the beamformer control input BFC_L and BFC_R may e.g. adjust the delay τ . It is well-known to the skilled artisan that by establishing and varying the delay τ in a delay-and-add/subtract based beamformer, the direction θ of maximum/minimum amplification is varied, i.e. the reception lobe of the beamformer is angularly shifted. As also disclosed in the WO 00/68703 and also preferably applied to the overall of the present invention, signal processing is performed in frequency mode and frequency-specifically. At the output of the histogram-forming units 44 the instantaneously prevailing DOA-dependent histograms are present and signals or data dependent there from are fed to a histogram classification unit 46. Therein, the histogram courses resulting from left ear and right ear acoustical signal reception are evaluated, thereby preferably including comparing the histogram courses as prevailing at the units 44_L , 44_R .

[0084] In unit 46 on one hand the histogram courses per se are evaluated, e.g. and with an eye on fig. 8 on peaks, width of the peaks, time behavior of the peaks etc., and the acoustical surrounding with respect to acoustical sources therein is respectively classified, as e.g. under the aspect of "acoustical source moving away", "acoustical source moving in the surrounding", "acoustical source becoming less relevant", "new acoustical source appearing", "acoustical source disappearing", "head of the individual moving", etc. Additionally the interrelation of both histogram courses is evaluated, thereby detecting how one of the histogram courses alters or appears with respect to the other side histogram course. This is for instance caused by the respective $HRTF_L$ and $HRTF_R$ becoming at the left and right ears (L, R) differently effective in dependency of DOA. Instead of performing classification on the basis of DOA according to the second aspect of the present invention other classifications may be exploited as for

instance described in the WO 02/32208 of the same applicant which accords with the US application no 10/059 059.

[0085] At the output of histogram classifying unit 46 there are generated control signals or data dependent on the classification result and from preset classification-dependent settings to be realized at the hearing device system. Thereby at the output of classification unit 46 a signal or data is generated, which is operationally connected to the beamformer control input BFC_L and BFC_R and on the other hand there is generated a control signal or data input to the weighting unit 49, which accords to the unit 9_W of the system of fig. 7. The beamformer control data and respective output is shown at BFC in fig. 9, the weighting unit control signals or data and respective output of unit 46 by SC. The SC signals or data do control, as was more generically shown in fig. 6 at the output of unit 12_W , the weighting unit 49 in that, shown by varying weighing coefficients α to γ in Fig. 6, the weights or transfer functions with which the output signals at outputs A_{1L} , A_{1R} respectively act upon electrical/mechanical converters 47_L and 47_R .

[0086] To further explain the embodiment of fig. 9 let us make an example. To start with there shall appear in the $\phi = 0$ DOA-direction with respect to the units 40 a significant acoustical source. The beamformers of the units 40 have their lobe directed on that source defining for $\phi = \theta = 0$. Both histograms at unit 44 may have e.g. a course as shown in fig. 8(a). The histogram classification unit 46 recognizes histogram peaks for $\phi = 0$ at both histograms, and this defines at unit 46 for a yet stable and significant acoustical source. Accordingly by means of BFC the beamformers are kept on $\theta = 0$. The SC control signal controls the selection unit 49 for equally weighted influence of signals or data appearing at both outputs A_{1L} , A_{1R} upon the converters 47.

[0087] Now let's assume this relevant acoustic source in the acoustical surrounding U starts to move to the right-hand side of fig. 9. This is recognizable at unit 46, because both histogram courses will show a development according to fig. 8(d). Thus, unit 46 recognizes: "source is moving to the right". As the acoustical source considered leads still to a significant sharp peak in both histogram courses, the beamformers of units 40 are both controlled by the control signals or data BFC to follow that source. Still the SC control signals control selection unit 46 at least nearly for equally distributed weighting of the influence of the output signals A_{1L} and A_{1R} upon the converters 47_L and 47_R .

[0088] As the acoustical source moves further to the right the head-related transfer function HRTF starts to influence the acoustical signals as impinging on the units 40. Whereas the right-hand side received acoustical signals will not be affected by the HRTF, the left-hand side received acoustical signals from that source become more and more influenced by HRTF as the acoustical source becomes "hidden" by the individual's head H. Therefore, the histogram course at unit 44_R will

still have a pronounced peak representing the source considered; whereas due to the HRTF the histogram course at unit 44_L will show at the angular position of the source considered, which is equal to the angular position of the peak in the histogram course at unit 44_R, a more and more enlarged, less pronounced peak. This is, purely as an example, shown in fig. 9 aside the histogram-forming units 44 and with respect to the same angular position φ_S of the acoustical source considered. The classifying unit 46 recognizes by comparing the two histogram courses that at the same angular position φ_S the left side histogram course has a widened and less pronounced peak with respect to the right-hand histogram course. This indicates the type of acoustical surrounding according to which a moving acoustical source has moved so far to the right that the respective HRTF function becomes effective. This means that the data from that source processed in the left ear unit 40_L become less accurate than the data processed in the right ear unit 40_R from that source and therefore the selection unit 49 is controlled to react on this specific exemplified situation by increasing the influencing of the right side signals or data at output A_{1R} upon the converters 47_L and 47_R. Thereby and e.g. within unit 49 the HRTF_L function, which takes effect on the acoustical signals impinging upon the left side unit 40_L, will be maintained with respect to data operationally acting upon converter 47_L in a most preferred mode, so as to maintain for the individual spatial perception of the acoustical source. With respect to beam control, as the DOA data of the right ear unit 40_R become according to this example more accurate than the respective data from unit 40_L e.g. due to higher level acoustic signals, also beamformer control will preferably be at least dominated by the DOA data from the right ear unit 40_R (not specifically shown in fig. 9).

[0089] The weighting-coefficients or functions as of α to γ of fig. 6, are preferably complex valued, frequency or frequency band dependent functions. In the classifier unit also multiple acoustical source situations are detected and predetermined strategies are set, how to control on one hand the beamformers, on the other hand the signal transmission at weighting unit most suitably for specific acoustical surroundings.

[0090] Thus, by combining the two aspects of the present invention a binaural hearing device system is achieved, which incorporates "Intelligent" system adjustment based on the evaluation of DOA histogram course.

[0091] Once again it must be emphasized that the data or signal processing functions which have been explained as by fig. 9 may be split in a great variety of realization modes to the two hearing devices or may be centralized within a unit remote from the hearing devices, and accordingly the signal transmission link 5 from one ear side to the other will be provided. Further, the skilled artisan recognizes that the system as of fig. 9 will incorporate different digital processing unit DSPs, espe-

cially along the double-arrowed operational connections so as to take into account specific hearing improvement needs at both individual's ears. HRTF functions etc.

[0092] As we have mentioned before one approach, which is today a preferred one, for and as a second aspect of the present invention is to provide classification of the acoustical surrounding of an individual so as to appropriately control a hearing device, being it a monaural or a binaural hearing device, based on evaluation of the direction of arrival DOA.

[0093] An approach how to determine the DOA is, as was explained before, explained in detail in the WO 00/68703. Based on that teaching, in fig. 10 there is exemplified a binaural hearing device system whereat on one hand and according to the first aspect of the present invention combined data or signals from at least two input acoustical/electrical converters are respectively transmitting from one ear side to the other or in the case of a CIC-device with one input converter after having been processed by a Wiener-Filter. On the other hand the embodiment of fig. 10 incorporates also the second aspect of the present invention realised on the basis as disclosed in the WO 00/68703. A left ear reception unit 50_L comprises two beamformers one defining a maximum amplification characteristic in DOA = 0° direction, the other one in the backwards DOA = 180° direction. In fig. 10 the beamformers are exemplified as being equal first order cardioid beamformers.

[0094] Unit 50_L outputs at respective outputs A_{50L1} and A_{50L2} signals or data dependent on the impinging acoustical signals amplified by the respective DOA dependent amplification of the beamformers and frequency dependent.

[0095] These signals are respectively denoted in fig. 10 by S_{F1} and S_{B1}. This output signals are led after analogue/digital conversion (not shown) to time domain/frequency domain conversion units 52_{L1} and 52_{L2} resulting in frequency specific output signals or data C_{B1} and C_{F1}. Signals dependent from the output signals of the conversion units 52 are further fed to absolute value forming units 54_{L2} and 54_{L1} outputting respective frequency specific signals or data |C_{B1}| and |C_{F1}|. These absolute value signals or signals dependent there from are fed to a quotient forming or division unit 56_L outputting for left ear reception unit 50_L frequency specific a quotient Q_L. Signals or data dependent from that quotient Q_L are subjected to histogram forming in a histogram forming unit 58_L outputting of histogram data H_L.

[0096] The right ear side with right ear reception unit 50_R up to data H_R is preferably construed exactly equally to the left ear side as just described and will therefore not specifically be described again.

[0097] The histogram data from the two histogram forming units 58_L and 58_R are input to a classifying unit 60.

[0098] Further, signals dependent on the front-forwards beamformers at both reception units 50_L and 50_R namely |C_{F1}| and |C_{F2}| are fed to a further quotient form-

ing unit 62_V and in analogy signals dependent from the output signal of the rear beamformers of both reception units as of IC_{B1} and IC_{B2} are fed to still further quotient forming unit 62_{Re}. Signals or data dependent from the result at the said quotient forming units 62_V and 62_{Re} are input to respective histogram forming units 64_{Re} and 64_V. The histogram data output by these histogram forming units are again input to the classification unit 60. [0099] After classification, e.g. as will just be discussed, the classification unit 60 generates output signals or data which are operationally linked to a control input of the weighting unit 61. As a function of the classification result data output by classification unit 60 signal transfer within weighting unit 61 is controlled, namely:

- from an input E_{L1} to which signals dependent from the forward beamformer of unit 50_L are fed to output A_L and output A_R respectively,
- from an input E_{L2} to which signals or data dependent from the output signals of the rear beamformer of unit 50_L are fed respectively to the output A_L and A_R
- and in complete analogy, from the right ear input E_{R1}, E_{R2} and to the said respective outputs A_L and A_R. The signals output at A_L and A_R are operationally fed to the output electrical/mechanical converters 63_L and 63_R respectively.

[0100] We define:

$$Q_L = \frac{|C_{F1}|}{|C_{B1}|}$$

$$Q_R = \frac{|C_{F2}|}{|C_{B2}|}$$

$$Q_{Re} = \frac{|C_{B1}|}{|C_{B2}|}$$

$$Q_V = \frac{|C_{F1}|}{|C_{F2}|}$$

[0101] Let's discuss possible classification results and criteria exploited and generated at unit 60 whenever an acoustical signal source in the surrounding U is detected with different DOA's.

[0102] Whenever DOA φ is between 0° and 90° following is valid:

$$Q_L > 1 \text{ and } Q_V > 1.$$

[0103] It has to be noted that it is preferred to consider Q_V in this case than Q_{Re} because the acoustical signal impinges at the higher level on the forward beamformer of both units 50, the output signals of these beamformers being thus more accurate with respect to signal/noise than the output signals of the respective rear side beamformers.

[0104] The same is considered with respect to evaluating Q_L or Q_R, the signals leading to Q_L have a better signal/noise ratio than the signals leading to Q_R because as the target acoustic source moves towards 90° the right side HRTF more and more influences signals received at the right ear unit 50_R. These considerations are made also in the following cases to be discussed and are not repeated.

[0105] As the target source is located at the DOA φ between 90° and 180° the following is valid:

$$Q_L < 1 \text{ and } Q_{Re} > 1.$$

[0106] As the target source moves on to a DOA φ between 180° and 270° the following prevails:

$$Q_R < 1 \text{ and } Q_{Re} > 1.$$

[0107] Finally as the target source moves to a position between 270° and 360° the following prevails:

$$Q_R > 1 \text{ and } Q_V < 1.$$

[0108] Thus by evaluating these criteria, as a simplified example, within the classification unit 60 it is established around 360° where an acoustical source is located and accordingly in weighting unit 61 the respective signal transfer functions are set. As an example:

[0109] If the source is detected by the above criteria to be located at a DOA between 90° and 180° the rear side beamformer of left ear reception unit 50_L will become master beamformer because that beamformer outputs a signal with best signal/noise ratio. Therefore the transfer functions or coefficients according to fig. 6 from input E_{L2} on the one hand to A_L and on the other hand to A_R will become governing. Thereby the transferred function from E_{L2} to A_R will consider the HRTF which is not influencing at the source position discussed signals impinging on the reception unit 50_L but which must be considered for driving the right output converter 63_R so as to maintain spatial source perception. Simplified the forward beamformer of unit 50_L and both beamformers at unit 50_R become slaves and their respective output signals are merely exploited to generate the respective quotients to allow the classification unit 60 to properly classify the prevailing DOA so as to properly control signal transfer in weighting unit 61.

Claims

1. A method for producing control signals or data at a hearing device for controlling a signal transfer characteristic of acoustical signals impinging on said device to electrical signals driving at least one electrical/mechanical output converter of said device, comprising the steps of generating first signals or data which are indicative of direction of arrival of acoustical signals impinging on a sensing area of said device and generating said control signals or data in dependency of said first signals or data. 5
2. A method of controlling signal transfer of acoustical signals impinging on a sensing area to electrical signals driving at least one electrical/mechanical output converter in a hearing device comprising the steps of generating at said device first signals or data which are indicative of direction of arrival of acoustical signals impinging on said sensing area and controlling said signal transfer by control signals or data in dependency of said first signals or data. 10 15 20
3. The method of claim 1 or 2, further comprising generating in dependency of said first signals or data a histogram and generating said control signals or data in dependency of said histogram. 25
4. The method of claim 3, further comprising the step of classifying said histogram and generating different control signals or data in dependency of the result of said classifying. 30
5. The method of claim 4, said step of classifying said histogram comprising the steps of classifying said histogram comprising classifying according to at least one of the following criteria: 35
 - angular location and/or movement of an acoustical source with respect to said device and/or other sources 40
 - distance and/or its time evolution of an acoustical source with respect to said device and/or to other sources 45
 - significance of an acoustical source with respect to other acoustical sources
 - angular movement of the device with respect to acoustical sources
6. The method of claim 1 or 2, further comprising the steps of providing said hearing device with a beamformer characteristic defining for amplification between an acoustical signal impinging on said device and an electrical signal or data in dependency of direction of arrival of said acoustical signal with respect to said device, controlling said at least one signal transfer characteristic comprising controlling said beamformer characteristic. 50
7. The method of claim 6, further comprising generating in dependency of said first signals or data a histogram and controlling at least said beamformer characteristic in dependency of said histogram. 55
8. The method of claim 7, further comprising the step of classifying said histogram and generating different control signals or data in dependency of the result of said classifying.
9. The method of claim 8, said step of classifying said histogram comprising the step of classifying said histogram according to at least one of the following criteria:
 - angular location and/or movement of an acoustical source with respect to said device and/or other sources
 - distance and/or its time evolution of an acoustical source with respect to said device and/or to other sources
 - significance of an acoustical source with respect to other acoustical sources
 - angular movement of the device with respect to acoustical sources and controlling at least said beamformer characteristic in dependency of at least one result of said classifying under at least one of said criteria.
10. The method of one of claims 1 or 2, comprising the steps of generating said first electrical signal in dependency of acoustical signals impinging upon a first acoustical receiver, generating second electrical signals in dependency of acoustical signals impinging upon a second acoustical receiver, driving a first electrical/mechanical converter with third electric signal and a second electrical/mechanical converter with fourth electric signal and controlling by said control signals or data at least one of
 - the transfer characteristic from said first electrical signal to said forth electric signal
 - the transfer characteristic from said second electrical signal to said forth electric signal
 - the transfer characteristic from said first electrical signal to said third electric signal
 - the transfer characteristic from said second electrical signal to said third electric signal.

11. The method of claim 10, further comprising generating in dependency of at least one of said first and of said second electric signals at least one histogram and controlling at least one of said transfer characteristics in dependency of said at least one histogram. 5
12. The method of claim 11, further comprising the steps of classifying said at least one histogram and differently controlling said at least one transfer characteristic in dependency of results of said classifying. 10
13. The method of claim 12, further comprising the step of controlling said at least one transfer characteristic in dependency of at least one result under at least one of the following classifying criteria: 15
- angular location and/or movement of an acoustical source with respect to said device and/or other sources 20
 - distance and/or its time evolution of an acoustical source with respect to said device and/or to other sources 25
 - significance of an acoustical source with respect to other acoustical sources
 - angular movement of said device with respect to acoustical sources. 30
14. The method of claim 10, further comprising the step of reintroducing a head-related transfer function in at least one of said transfer function from said first signal to said fourth signal and from said second signal to said third signal. 35
15. A hearing device with an acoustical/electrical input converter arrangement with an output, an electrical/mechanical output converter arrangement with an input, a direction of arrival determining unit with an input operationally connected to said output of said acoustical/electrical converter arrangement and generating at an output a signal or data indicative of direction of arrival of acoustical signals impinging on said acoustical/electrical input converter arrangement, a controlled signal transfer unit the input thereof being operationally connected to the output of said acoustical/electrical input converter arrangement, the output thereof being operationally connected to the input of said electrical/mechanical output converter arrangement and providing for controlled signal transfer between said input and said output and having a control input being operationally connected to the output of said direction of arrival determining unit. 40 45 50 55
16. The device of claim 15 further comprising a histogram forming unit interconnected between said output of said direction of arrival determining unit and said control input of said controlled transfer unit.
17. The device of claim 16, further comprising a classifying unit interconnected between an output of said histogram forming unit and said control input of said controlled transfer unit.
18. The device of claim 15, being a binaural hearing device said acoustical electrical input converter arrangement comprising a left ear and a right ear acoustical/electrical input converter subarrangement, said electrical/mechanical output converter arrangement comprising a left ear and a right ear electrical/mechanical output converter subarrangement, said controlled transfer unit controlling signal transfer from said right ear input converter subarrangement to both said left ear and said right ear electrical/mechanical output converter subarrangements and from said right ear electrical/mechanical input converter subarrangement to both said left ear and said right ear electrical/mechanical output converter subarrangement.
19. The method of claim 1 or 2, said hearing device being a hearing aid device.
20. The device of claim 15 being a hearing aid device.
21. A method of manufacturing a hearing device comprising
- providing at least one device casing
 - providing in said casing an acoustical/electrical input converter arrangement with an output
 - providing an electrical/mechanical output converter arrangement, with an input in at least one of said at least one casings
 - providing a direction of arrival determining unit in at least one of said at least one casings, with an input and with an output
 - providing a controlled signal transfer unit in at least one of said at least one casings with an input, an output and a control input
- and establishing following operational connections:
- between said input of said direction of arrival determining unit and said output of said input converter arrangement
 - between said input of said transfer unit and said

- output of said input converter arrangement
- between said control input and said output of said determining unit
 - between said output of said transfer unit and said input of said output converter.
22. The method of claim 21, comprising establishing at least a part of said connections before providing said units, and/or said converter arrangement and/or said output converter in the respective casing.
23. A binaural hearing device system preferably according to at least one of claims 15 to 18, comprising a first device for one ear of an individual, a second device for the other ear, a data communication link between said first and said second devices, said first device comprising at least a reception unit with at least two input acoustical/electrical converters and a signal processing unit, the inputs thereof being operationally connected to the electrical outputs of said at least two converters and generating at an output a signal dependent on signals at both said inputs, said communication link being provided at the output side of said processing unit and transmitting signals dependent upon said output signal of said processing unit said second device comprising at least a output electrical/mechanical converter.
24. The binaural hearing device of claim 23, wherein said first device is a device to be completely introduced into individual's ear channel (CIC), wherein instead of said at least two input converters there is provided a single acoustical/electrical input converter and wherein instead of said processing unit with at least two inputs there is provided a processing unit with one input operationally connected to the output of said single input converter, said signal processing unit performing at least a Wiener filter operation upon the signal applied to said input.
25. The system of one of claims 23 or 24, wherein said first device for said one ear does not comprise an electrical/mechanical output converter.
26. The system of claim 23 or 24, wherein said second device for said other ear does not comprise an input acoustical/electrical converter.
27. The system of claim 23 or 24, wherein said first device for said one ear comprises an output electrical/mechanical converter unit, the input thereof being operationally connected to the output of said processing unit.
28. The system of claim 23 or 24, wherein said reception unit is a first reception unit, said at least two input acoustical/electrical converters are first acoustical/electrical converters at a first reception unit, said signal processing unit is a first signal processing unit, said output electrical/mechanical converter is a second output electrical/mechanical converter, said first device comprising a first output electrical/mechanical converter, said second device comprising a second reception unit with at least one second input acoustical/electrical converter.
29. The system of one of claims 23 or 24, wherein said data communication link is a wire-bound, an optical fiber or a wireless communication link.
30. The system of claim 28, wherein said second reception unit comprises at least two second input acoustical/electrical converters and a second signal processing unit.
31. The system of claim 30, wherein the inputs of said second signal processing unit are operationally connected to the outputs of said second input converters and generates at a second output a signal dependent on signals at both said inputs of said second signal processing unit, said data communication link being provided additionally at the output side of said second signal processing unit.
32. The system of claim 30 or 31, the output of said first signal processing unit being operationally connected to a first input of a weighting unit, the output of said second signal processing unit being operationally connected to a second input of said weighting unit, said weighting unit having a first output operationally connected to the input of said first output converter and a second output operationally connected to the input of said second output converter, said weighting unit having a control input, said weighting unit varying operational connection of said first input to said first output, from said first input to said second output, from said second input to said first output and from said second input to said second output, controlled by a signal applied to said control input.
33. The system of claim 32, wherein said operational connections comprise frequency dependent, complex transfer functions.
34. The system of claim 32, wherein said control input is operationally connected to the output of a classification unit with at least one input operationally connected to at least one output of at least one of said reception units.
35. The system of claim 23 wherein said first device comprises a beamformer unit with a beamcontrol input and with an output, a detection unit for the di-

- rection of arrival of an acoustical signal impinging upon said reception unit and generating an output signal in dependency of said direction of arrival at an output, said output of said direction of arrival detection unit being operationally connected to said beamcontrol input of said beamformer unit.
36. The system of claim 34, further comprising a determination unit for the direction of arrival of an acoustical signal said determination unit being interconnected between said at least one input of said classification unit and said at least one output of said at least one reception unit.
37. The system of claim 36, further comprising at least one histogram forming unit the input thereof being operationally connected to said at least one output of said at least one reception unit, the output thereof being operationally connected to an input of said classification unit.
38. A method for controlling a hearing device system preferably according to at least one of claims 1 to 14, comprising at least a reception unit at a first device for one ear having at least two input acoustical/electrical converters and at least an output electrical/mechanical converter at a second device for the other ear and a communication link between said first and said second devices, comprising the steps of generating in dependency of output signals of said at least two input converters a combined signal and transmitting said combined signal via said communication link.
39. The method of claim 38, further comprising the step of providing instead of said at least two input converters only one converter and construing said first device as a device to be completely introduced into the ear channel, further comprising the step of treating the output of said one input converter by a Wiener-Filter and transmitting signals dependent from the output of said Wiener-Filter via said communication link.
40. The method of claim 38 or 39, further comprising the step of not providing an electrical/mechanical output converter at said first device.
41. The method of claim 38 or 39, further comprising the step of not providing an input acoustical/electrical converter at said second device.
42. The method of claim 38 or 39, further comprising the step of providing an output electrical/mechanical converter to said first device.
43. The method of claim 38 or 39, further comprising the step of providing at least one input acoustical/electrical converter at said second device and operating said output electrical/mechanical converter at said second device in dependency of said signal transmitted via said communication link and an output signal of said at least one input acoustical/electrical converter of said second device.
44. The method of claim 43, further comprising controlling signal transfer functions to a signal driving said output electrical/mechanical converter at said second device on one hand from output signals of said at least two input converters of said first device and on the other hand from an output signal of said at least one input converter of said second device.
45. The method of claim 44, further comprising the step of classifying signals dependent from at least two of the output signals of said at least two input converters at said first device and of said at least one input converter at said second device and controlling said transfer functions in dependency of a result of said classifying.
46. The method of claim 45, further comprising the step of determining direction of arrival of an acoustical signal impinging on said devices and performing said classification in dependency of said direction of arrival.
47. The method of claim 46, further comprising the step of generating at least one histogram indicative of time occurrence of directions of arrival and performing said classification in dependency of said histogram.
48. The method of claim 43, further comprising the step of providing at said first device an output electrical/mechanical converter.
49. The method of claim 48, further comprising the step of driving said output converter of said second device in dependency of output signals of said at least one of at least two input converters of said first device and in dependency of output signals of said at least one input converter of said second device and driving said output converter at said first device in dependency of output signals of at least one of said at least two input converters at said first device and in dependency of output signals of said at least one input converter of said second device.
50. The method of claim 49, further comprising the step of controlling said signal transfer functions of said dependencies between output signals of said input converters and said output converters.
51. The method of claim 50, further comprising performing a classification of signals dependent on at

least two output signals of said at least two input
converters of said first device and said at least one
input converter of said second device and control-
ling said dependencies between said output signals
of said input converters and said output converters 5
in dependency of results of said classification.

52. The method of claim 51, further comprising deter-
mining direction of arrival of acoustical signals upon
said devices; said classification comprising classi- 10
fying of said direction of arrival.

53. The method of claim 51, further comprising the step
of forming at least one histogram of a signal, said
classification comprising classifying the result of 15
said histogram forming.

54. The method of claim 48, said second device com-
prising at least two input converters. 20

55. A method preferably according to at least one of
claims 21 or 22, further for producing a drive signal
for an electrical/mechanical output converter of a
binaural hearing device comprising the steps of 25
acoustical/electrical converting impinging acousti-
cal signals at at least two input converters of a de-
vice to be applied adjacent or in individual's one ear,
transmitting a signal dependent from both said con-
verters via a link to a further device to be applied 30
adjacent or in individual's other ear and generating
said drive signal in dependency of said transmitted
signal.

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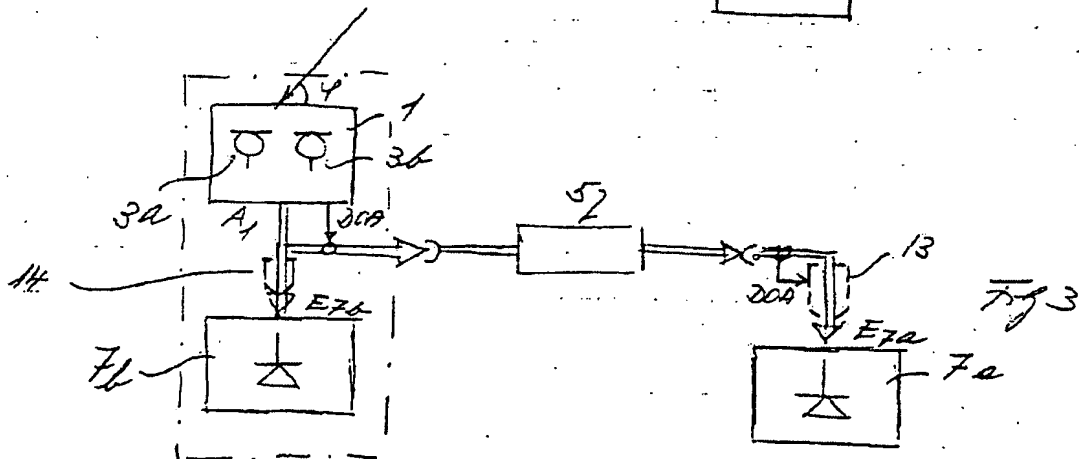
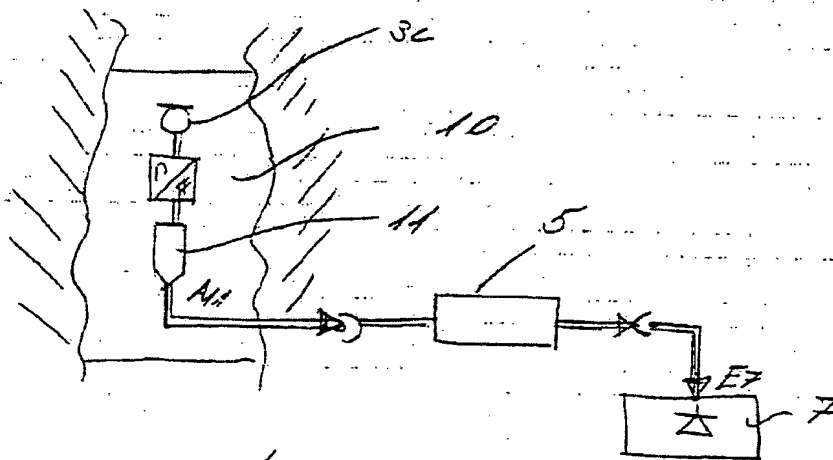
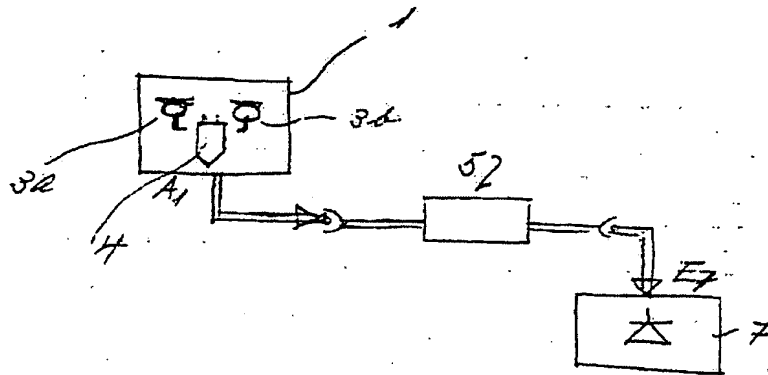
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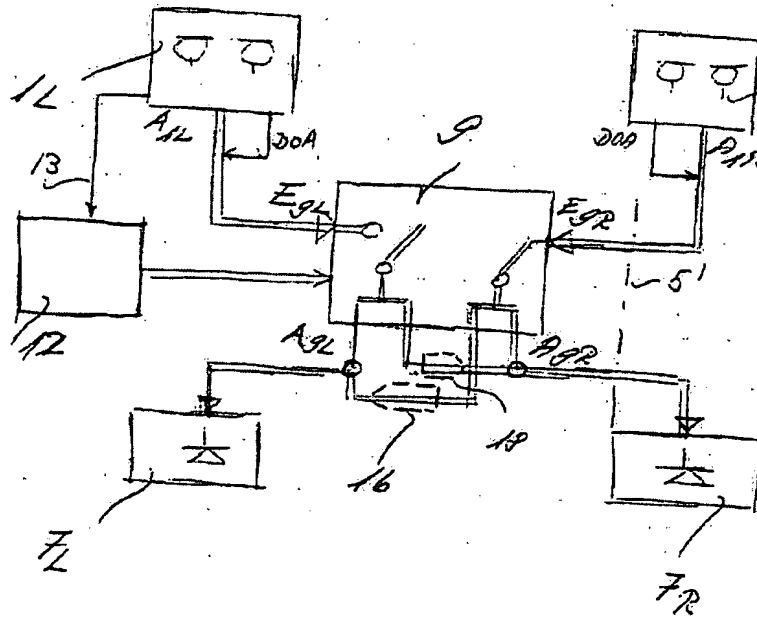


Fig. 4

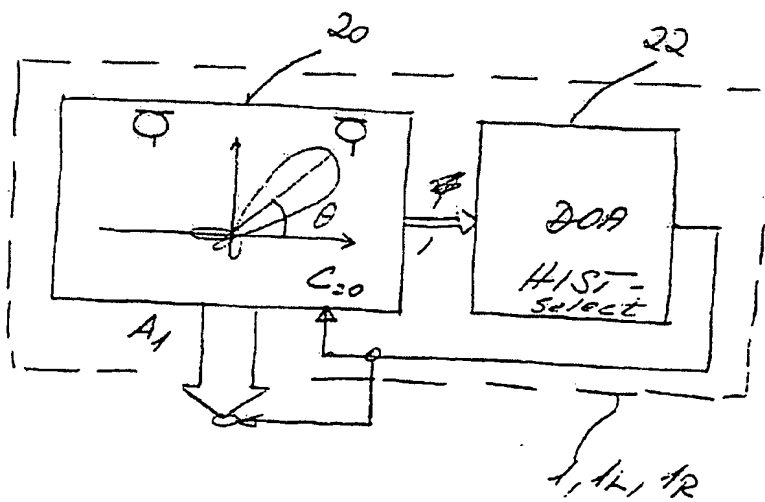
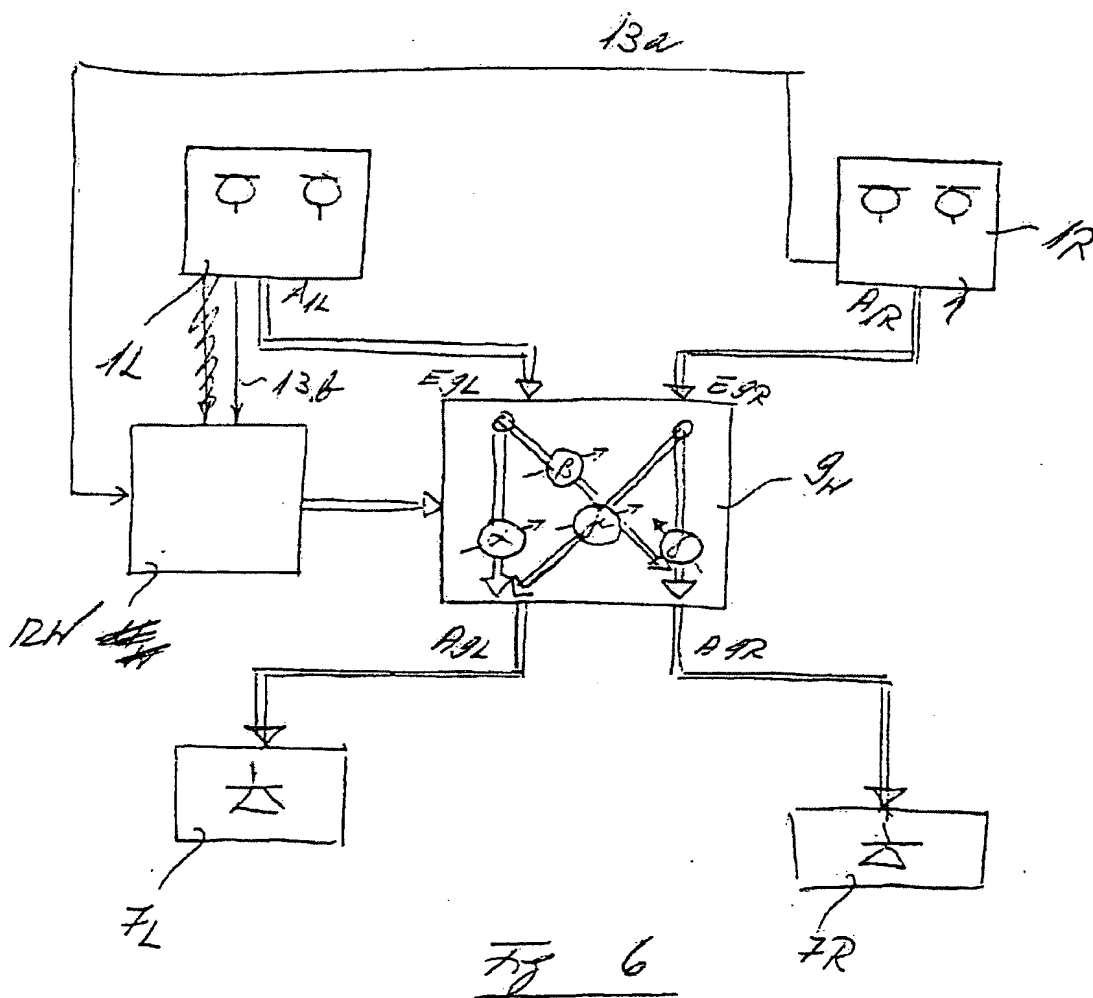


Fig. 5

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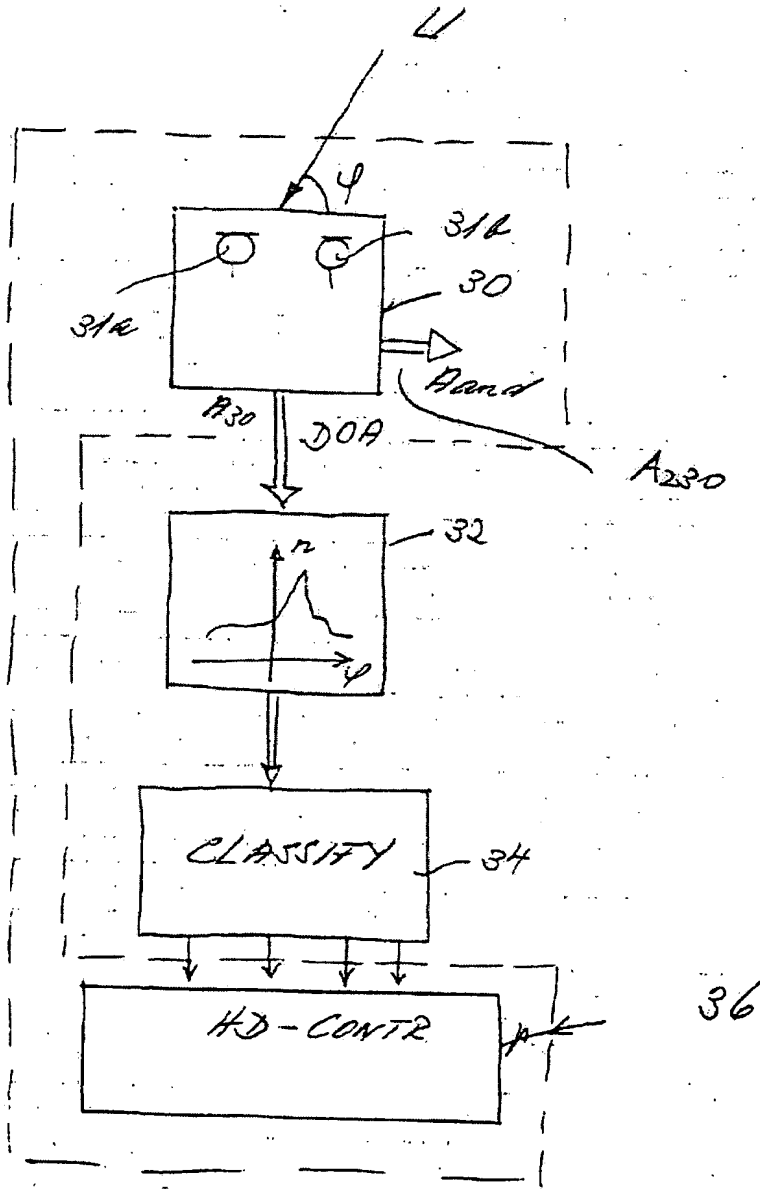


Fig 7

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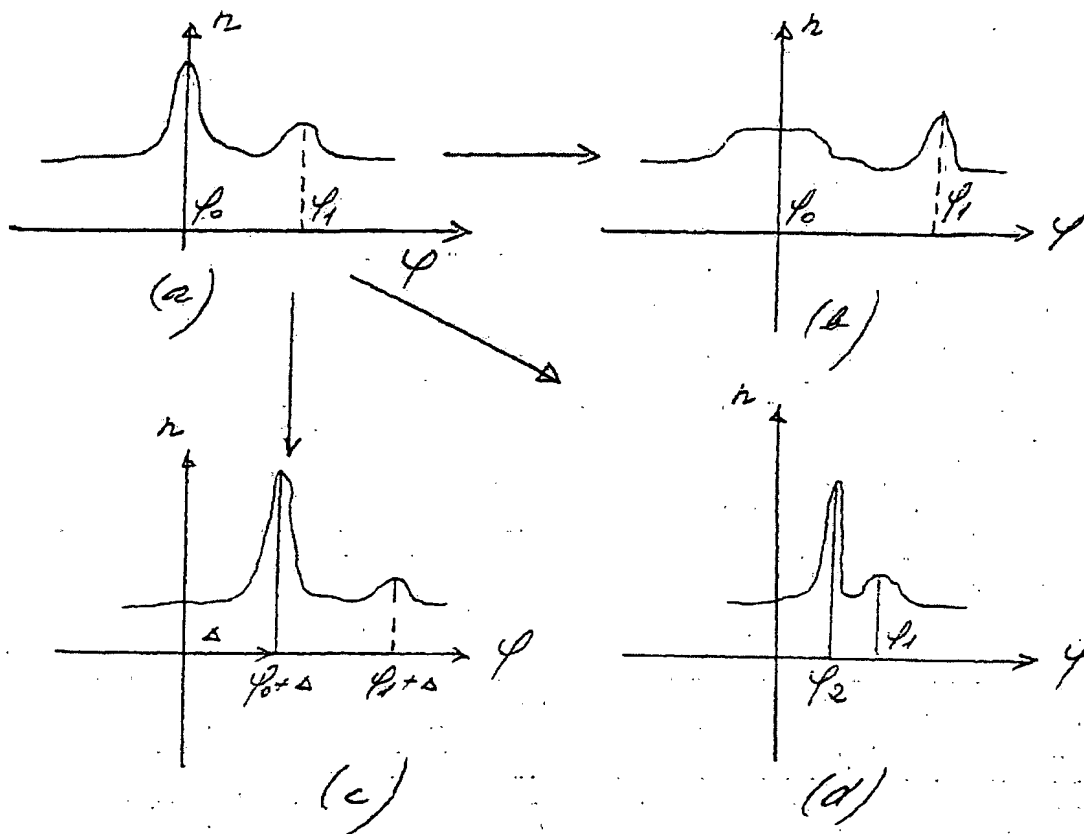
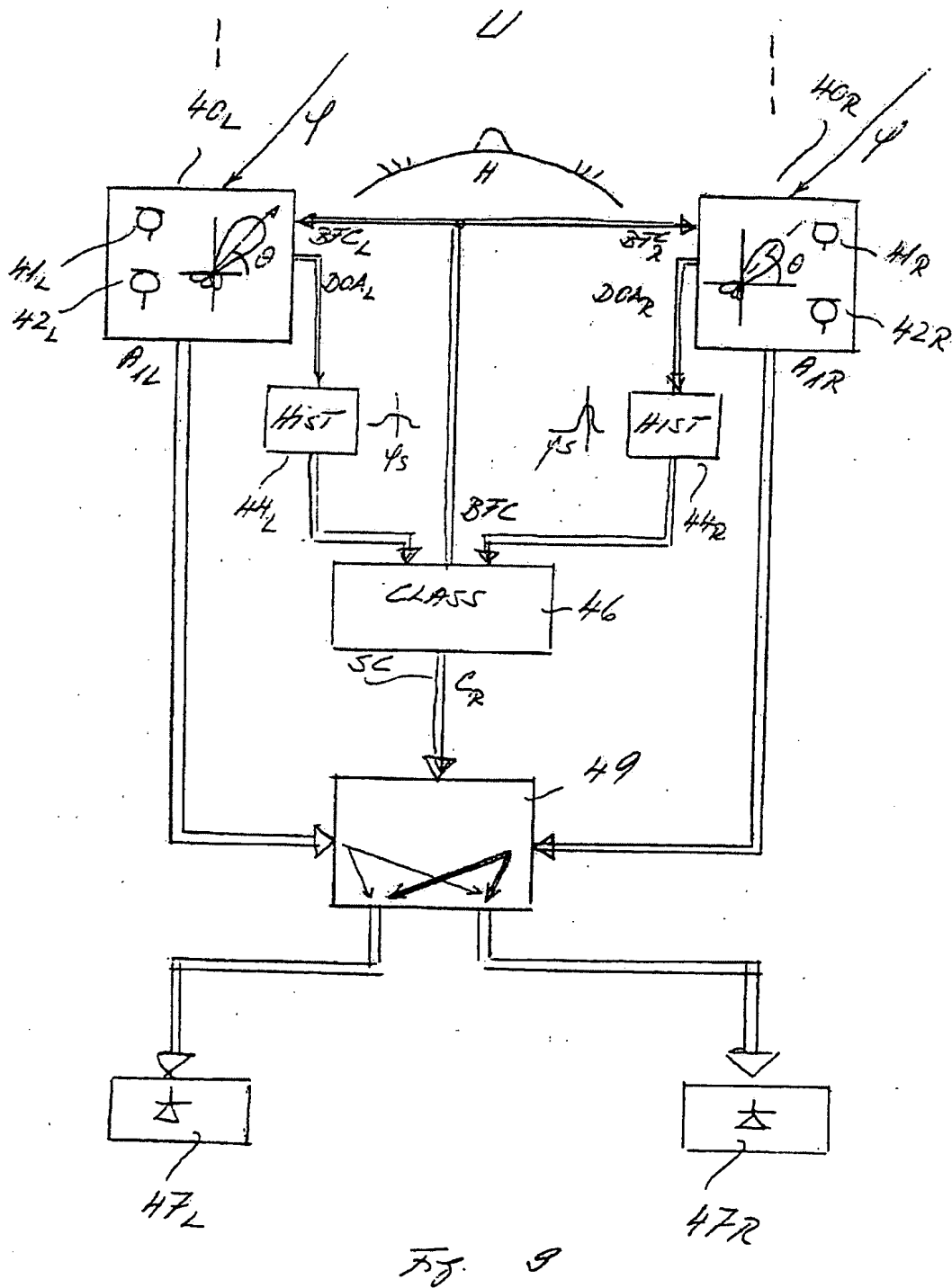
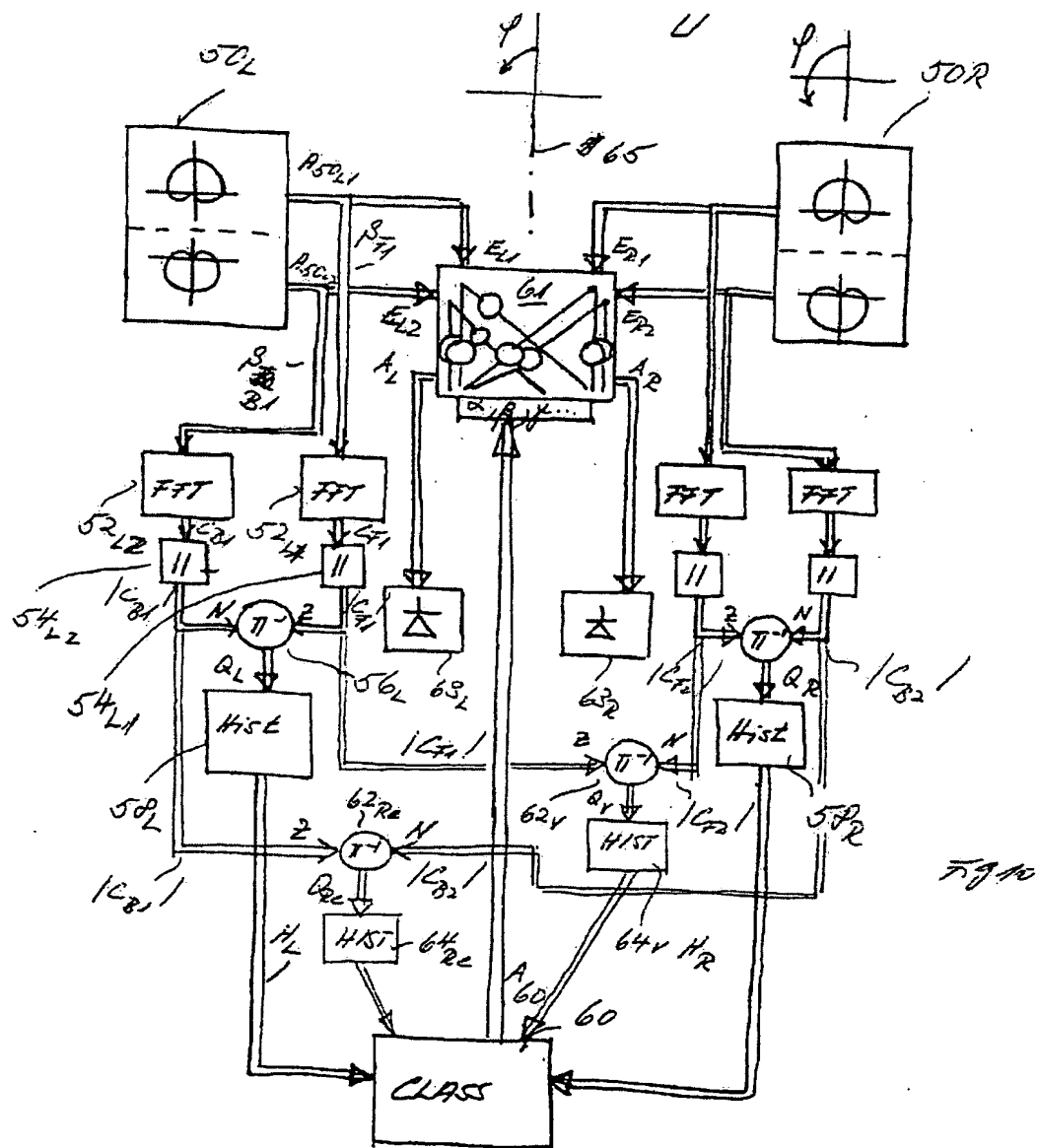


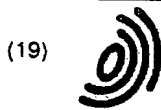
Fig 8

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(11) **EP 1 326 478 A3**

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(54) **Method for producing control signals, method of controlling signal transfer and a hearing device**

(57) Acoustical signals from the acoustical surrounding (U) which impinge upon a reception unit 30 are evaluated and direction of arrival (DOA) of such signals is determined. From signals indicative of such direction of arrival (DOA) a histogram is formed in unit 32. The behaviour of such histogram is classified under different aspects or criteria and dependent on classification results in a classifying unit 34 the hearing device and thereby especially its signal transfer characteristic from input acoustical signals to output mechanical signals is controlled or adjusted.

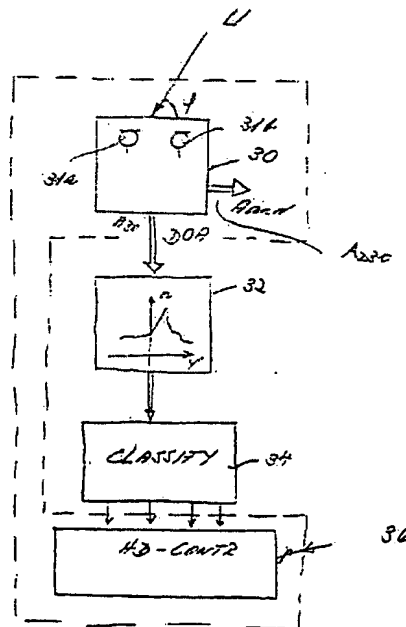


Fig. 7

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European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 03 00 5179

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
D,X	WO 00 68703 A (PHONAK AG ; ROECK HANS UELI (CH)) 16 November 2000 (2000-11-16)	1-3, 6, 7, 11, 15, 16, 19, 20, 11	H04R3/00 H04R25/00
Y	* the whole document *		
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			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
			H04R
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 30 April 2003	Examiner Gerken, S
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons a : member of the same patent family, corresponding document</p>			

EPO FORM 1503 03/03 (PC/COI)



European Patent
Office

Application Number

EP 03 00 5179

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- ☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):
- ☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- ☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- ☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.
- ☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:
- ☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-13, 15-20



European Patent
Office

LACK OF UNITY OF INVENTION
SHEET B

Application Number

EP 03 00 5179

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-13,15-20

Classifying a histogram generated in dependency of signals which are indicative of direction of arrival of acoustical signals, and generating different control signals or data in dependency of the result of said classifying.

Object: To allow evaluation or detection not only of different behaviours of the acoustical surrounding itself, but additionally of the behaviour of the device and thus of the individual in the acoustic surrounding (cf. claims 4, 8, 12, 17).

2. Claim : 14

Reintroducing a head-related transfer function in at least one of the transfer functions between an acoustical receivers and an electrical/mechanical converters. Object: To allow spatially correct perception of the acoustical signal even if an acoustical source is angularly located so that it appears acoustically shadowed or masked by the individual's head.

3. Claims: 21,22

Manufacturing a hearing device comprising the steps of providing a casing, providing certain units and establishing certain operational connections between the units, wherein at least some of the connections are established before the units are provided. Object: To simplify manufacturing of the device.

4. Claims: 23,25-38,40-55

A binaural hearing device system having a data communication link between a first device for one ear and a second device for the other ear, the first device comprising at least two input acoustical/electrical converters and a signal processing unit and the second device comprising at least an output electrical/mechanical converter. Object: To reduce the amount of data which are transmitted via the link as compared to the case where there is a respective input converter in each of the first and second devices and output signals of each input converter are separately transmitted via the link.

5. Claims: 24,25-34,36,37,39-54



European Patent
Office

LACK OF UNITY OF INVENTION
SHEET B

Application Number
EP 03 00 5179

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

A binaural hearing device system having a data communication link between a first device for one ear and a second device for the other ear, the first device being a device to be completely introduced into the ear channel (CIC) and comprising a single input acoustical/electrical converter and a signal processing unit and the second device comprising at least an output electrical/mechanical converter, wherein the signal processing unit is adapted to perform at least a Wiener filter operation upon the signal applied to its input. Object: To achieve information and data reduction before transmitting data to the communication link.

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 03 00 5179

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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30-04-2003

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